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Redesign of the External Tank's Bipod Fitting

When the Space Shuttle returns to flight, the External Tank will have a newly redesigned bipod fitting -- one that removes all foam from the top of the fitting, including the foam insulation ramp, or the bipod ramp. Space Shuttle Columbia accident investigators believe insulating foam from Columbia's left bipod ramp broke off during liftoff of the Shuttle's STS-107 science mission on Jan. 16, 2003, and struck the Orbiter's left wing. The new design meets the recommendation of the Columbia Accident Investigation Board to minimize potential debris by eliminating the foam ramp and replacing it with heaters.

The new design also meets the four objectives established by the External Tank Project Office's redesign team: It creates no new risks; eliminates the possibility of a foam ramp failure; it can be certified for flight and implemented quickly; and it can be retrofitted to the existing fleet.

The External Tank Project Office began its redesign efforts prior to the loss of Columbia -- after insulating foam from the left bipod ramp area came off during the launch of Space Shuttle Atlantis on the STS-112 mission in October 2002. During the launch of Columbia on its STS-107 mission in January 2003, a similar loss prompted NASA's Office of Space Flight to mandate a redesign of the bipod ramp before the Shuttle fleet could return to flight.

The bipod ramp was a wedge-shaped foam structure, approximately 30 inches long, 14 inches wide and 12 inches tall. The ramp was designed to protect the bipod fitting, which is near the front of the Space Shuttle at the point where the External Tank attaches to the Orbiter. The foam ramp protected the fitting from aerodynamic loads during liftoff and prevented ice from forming on the fitting when the liquid hydrogen tank was filled prior to launch. The ramp was made during the final stages of the tank's preparation by hand-spraying BX250/265 foam and carving it into a ramp shape.



Bipod Fitting

Design Changes

The new bipod fitting design will allow the fitting to fly bare -- minus the insulating foam ramp -- but still capable of withstanding aerodynamic heating. The design consists of a bare bipod fitting with four rod heaters mounted below the fitting to prevent ice and frost from forming when the External Tank's hydrogen tank is filled. The fitting itself is the same basic design as the one now used on the External Tank.

The new design includes four rod heaters -- only two heaters are needed; the other two are redundant or back-up heaters. The heaters are placed below the fitting in heater retaining covers made of Inconel 718, a strong alloy composed of nickel, chromium and iron. The heaters sit on top of a copper plate sandwiched between the fitting and the phenolic isolator that attaches to the tank. The phenolic isolator is a

thermal pad of laminated, fiberglass-reinforced material that is made with a phenolic resin -- a hard, dense material made by applying heat and pressure to layers of paper or glass cloth impregnated with synthetic resin. The isolator separates the heater from the tank.

The heaters are cartridge-type heaters with a wire coil inserted into a tube filled with magnesium oxide. They are 0.25 inches in diameter and 5 inches in length. Each cartridge is a 300-watt heater and operates at 120 volts AC.

Other changes include the elimination of the hole in the spindle face that once provided clearance for the bipod spindle heater element. That heater was removed once the four rod heaters were placed beneath the spindle. The elimination of the spindle heater meant a smaller end cover could be used on the fitting. Once the spindle heater was removed, the end cover's only purpose was to protect the internal bearing surfaces from dust, sand and other debris that could impact the its ability to rotate freely.

To ensure the bare spindle end cover can withstand the aerodynamic heating experienced during launch, the cover is now made of Inconel 718, which can withstand temperatures of up to 2,000 degrees Fahrenheit.

The new design also requires additional cabling to operate the heating system. It includes eight circuits -- four for each bipod -- that run from the External Tank Ground Umbilical Carrier Plate to the heaters under the bipod fitting.

The new design is an alternative derived from three original redesign options proposed by the project office to the Space Shuttle Program Requirements Change Board on May 9, 2003, and later presented by the Columbia Accident Investigation Board to the public.

Testing

Testing is an important factor in any redesign or modification because it validates the integrity of the design. Though testing cannot duplicate actual

flight, it can significantly reduce risk because it allows for careful observation and precise control over the test article. The new bipod fitting design has undergone wind tunnel tests, vibration and structural tests, and thermal tests, during both its design and implementation phases, to certify it is ready for flight. These tests ensure the new design does not affect the current External Tank loads and stresses.

Structural tests performed at NASA's Michoud Assembly Facility in New Orleans demonstrated the load capability -- an external force or other action acting on a structure -- of the redesigned fitting. Tests demonstrated the effects of cryogenic -- subzero -- temperatures at the External Tank's intertank/flange area and the effects of ascent temperatures.

Thermal testing performed at Eglin Air Force Base, Fla., demonstrated that the redesign does not permit ice or frost to form during fueling of the hydrogen tank. Thermal tests were also used to duplicate the launch environment, recreating the temperatures, humidity and wind velocities experienced during liftoff.

Wind tunnel tests performed at Arnold Engineering Development Center at Arnold Air Force Base, Tenn., demonstrated the design's aerodynamic capabilities and its capacity to resist high temperatures generated during ascent.

Implementation of the new design

Once testing is completed on the new bipod fitting design and the new design has passed its final certification review, work is expected to begin in October 2003 to retrofit the new design on the eight tanks already completed. Once the design has been retrofitted on existing tanks, it will be implemented on new tanks.

Lockheed Martin Space Systems will do the work at NASA's Michoud Assembly Facility in New Orleans. Delivery of the retrofitted tanks to the Kennedy Space Center in Cape Canaveral, Fla., is expected in November 2003.